# UBICOMP-KAIZEN

*The use of Japanese Quality Management methods for the Design of Smart Buildings*

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**Abstract.** This paper describes the successful development of a design supporting method called 'Ubicomp-Kaizen' for the design of computer-integrated 'smart' buildings. The tool uses known methods of quality-management of the car-manufacturing industry and integrates them into the architectural design process. By this, the CAAD-topics 'design methodology', 'ubicomp/smart buildings', 'interactive architecture' and 'Building Information Model (BIM)' are involved. In result it proves the successful integration and application of tools known from the product development industry such as 'Quality-Function-Deployment (QFD)' and 'Failure Mode and Effects Analyze (FMEA)' within the iterative building design. The outlook formulates a side-result which is the setup of a digital decision supporting tool and the extension of the IFC-definitions in order to integrate aspects of user-interaction and ubicomp.

**Keywords:** design processing, building information modelling (BIM), methodology, sustainability, ubicomp, interdisciplinary.

## 1. Introduction

The basic foundation of 'Ubicomp-Kaizen' is 'Kaizen' (Japanese: 改善, meaning 'steady improvement'). Based on Kaizen, various tools and methods were developed by mainly Japanese engineers or theorists, such as Shingo and Akao. These tools are mainly applied in the production industry for quality assurance in both product development and process management. A well known user is Toyota Motor Company, the inventor of the 'Toyota Production System'. These tools and methods aim for efficiency, synchronisation, heterogeneity and quality improvement (Imai, 1992). Throughout the last 60 years, they proof to successfully work in various cultures, tasks and even disciplines such as software engineering and ship building. The results of applying Kaizen-based methods are: higher qualities, higher return-of-investment, higher client satisfaction, faster processing and better simultaneous collaboration of large numbers of stakeholders (Masing, 2007).

As computer-enhanced building-interaction is more and more becoming an essential customer demand, the building design process has to integrate it as fully respected issue. Its possibilities and impact has to be considered from the very first steps. This creates the driving question: '*How can architects deal with the fast changing specifications of ubiquitous computing, whereas a building usually sustains multiple decades?*'. In addition, architects have mainly little understanding of Ubicomp and its potential of networking heterogonous services. Ubicomp is seen as a novel building material with abnormal qualities concerning design-impact and lifecycle management (Schoch, 2006).

The paper's relevances to the field of CAAD are:

- investigative, creative and numeric design supporting approach, easily to be transformed into software.
- numeric valuating system, proofed to enhance quality.
- speeding up decision-making-processes in situations of large and heterogeneous solution spaces.
- expansion of the IFC-Definitions towards a BIM including the needs of building-user-interactions, resource management and ubicomp.

The paper is elaborated based on the point of view of a holistically arguing architect on the building design including Ubicomp. As usual design tasks can be broad; this paper considers the area only from building envelope to detailing. This relates to usual design scales from 1:500 to 1:10. The focussed building types are for housing, office and education purposes. The paper is based on experiences and standards from Germany, Austria and Switzerland. Their design processes are mainly based on either the 'École des beaux-Arts' or the 'Bauhaus'.

## 2. Method

In order to proof the usefulness of Japanese quality management (QM) methods within the design of computer integrated buildings, it first needs to define the fields which are affected. The fields are defined by these four topics:

1. quality management based on the Japanese philosophy of 'Kaizen'
2. building design and its process
3. ubicomp
4. resource management

The topic 'resource management' is added due to two primary reasons: (i) building design is simulating the construction, operation, update and demolition of a building. A large diversity of resources is therefore affected and needs to be considered either through calculation, simulation or assumption. The resources are as diverse as costs, material, space, people, energy, daylight, life-cycle, labour, etc. (ii) Ubicomp is mainly invisible (Weiser, 1991) but has strong impact on users and the building design though its indirect demands. These are caused by a modified behaviour of people or building elements. An example is the chain of impacts simple daylight-sensor can cause: by triggering a change of the sunshades, the solar input is changed which results in different thermal heat inside the building which causes HVAC to operate differently. This chain splits up to affecting users, visual appearance, comfort, etc.

Based on these four topics, their unique characteristic as well as their characteristics in relation to one of the remaining three topics is distilled. In order to allow a later analyze of the topics compatibility, the attributes are abstracted. If no source for fulfilling a certain criteria was found, or an unclear interpretation is expected, the attribute is not set. Figure 3 shows the results.

After checking the compatibility, the design process is expanded by selected tools of the Kaizen-based QM. The selection is done in relation to the attributes and the design task. Finally a simple test case for building design is used in order to develop the integration.

## 3. State-of-the-Art

Quality is defined as a goal to be reached. It is closely linked to Kaizen's consequent client-orientation. This means that a goal which has to be achieved is defined by so called 'clients'. When translating this into the field of building design, mainly a customer – either a person, a company or an institution – is initially acting as a client which decides to ask for a building. This results in a list of demands. Usually each of the demands triggers a series of consequent demands. By this, the demands develop themselves as clients for a future iteration loop. In the building design, these iterative aspects are known since long.

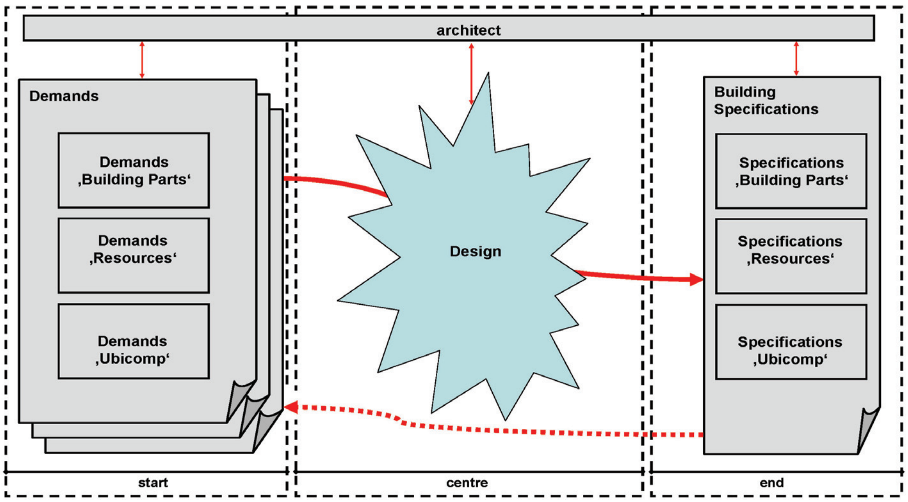


*Fig. 1: the schematic illustration of a generalized iterative design process with only few elements of quality management.*

In addition, solutions for the fulfillment of a specific demand cause themselves a series of new demands which varying flexibility and importance. Quality is therefore defined as one or a mix of specific standards to be achieved, such as costs, style, aesthetics, size, material, sustainability, etc. These aspects are formulated as demands to be fulfilled. Kaizen is further about the synchronization of processes and their subdivision into smaller more easily to understand units (Shingo, 1989). A generalized building design tasked as described above is illustrated in figure 1.

The process of industrial product development shows parallels to the building design process. Product development can successfully use Kaizen-based tools and methods (Liker, 2006). The danger of comparing characteristics of two diverging field is avoided. The two fields would be the management of serial production processes on the one side and the design of prototyped on the other side.

Tools that are based on the Kaizen philosophy are e.g. the ‘Quality Function Deployment (QFD)’ and ‘Fault Tree Analyses (FTA)’. As initiated by Akao, the QFD can be formalized as the so called ‘House of Quality (HoQ)’ (Akao, 1992). Figure 2 is a general description of the HoQ. Figure 2 shows its setup. It is worked through from (1) to (6).

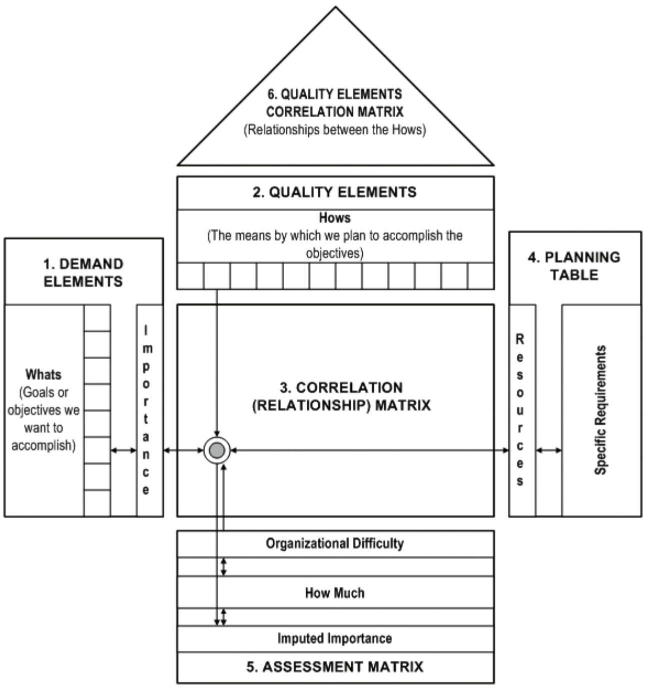


*Fig. 2: the relations and applications within a ‘Quality Function Deployment’ as proposed by Akao. It starts at no. 1 and considers at least areas 2,3 and 5 (based on image source: http://thecorporatetrainingsystem.com/Images/qfd.png : Dec 2008).*

The HoQ interconnects multiple matrixes. The core matrix is the correlation-matrix which correlated the demands with the proposed solutions. A numeric ranking is valuing the expected success of the solution when using a specific ‘quality element’. When handling the process of building design and quality management, two main observations are done:

1. compared with disciplines such as mechanical engineering, building design has low awareness about quality management processes although it practises various methods for QM which are considered novel in the production industry. The methods are e.g. ‘Design

Review Based on Failure Mode (DRBFM)' which can be performed as a multidisciplinary round-table meeting including minutes o meetings.

2. despite this controversy, the processes in the building design are rarely analysed in respect to their impact on quality, workflow, result, time-management, etc. This is considered as a lack within the discipline of architecture. Novel BIM software is partly trying to network the building design with assessment and QM tools.

With the advent of Ubicomp this design process is challenged, because Ubicomp is about to be visually vanishing, it is a service and it can have unpredictable life-cycles, in the meaning of either the service is aging and loosing its value such as an analogue building element, or it collects information during operation and therefore the value increases, or a change in the setup such as a software update destroys the service which makes it instantly out of value. An extension of the existing design process is proposed as architects have no expertise in the field of QM.

## 4. Development

The identification of the four topics attributes is summarized in figure 3. It illustrates the occurrence of each attribute. In result, the characteristics of Kaizen are matching 10 out of 29 attributes. An additional 11 attributes are found in at least one other topic. Only the attribute of being an 'established QM' seems to be self-referencing and therefore not linked to an other topic.

| | | | | topics | | | |
|---|---|---|---|---|---|---|---|
| | | | matches | QM | design | RM | ubicomp |
| A | 1 | **client-oriented** | 4 | 1 | 1 | 1 | 1 |
| | 2 | **synchronized** | 4 | 1 | 1 | 1 | 1 |
| | 3 | **get-principle** | 4 | 1 | 1 | 1 | 1 |
| | 4 | **heterogenous context** | 4 | 1 | 1 | 1 | 1 |
| | 5 | **holistic** | 4 | 1 | 1 | 1 | 1 |
| | 6 | **networked dependencies** | 4 | 1 | 1 | 1 | 1 |
| | 7 | **control circuits** | 4 | 1 | 1 | 1 | 1 |
| | 8 | **impact on structure and form** | 4 | 1 | 1 | 1 | 1 |
| | 9 | **impact on costs** | 4 | 1 | 1 | 1 | 1 |
| | 10 | **phase-based reasioning** | 4 | 1 | 1 | 1 | 1 |
| B | 11 | **integrated qualitymanagement** | 3 | 1 | 1 | | 1 |
| | 12 | **division of processes into smaller units** | 3 | 1 | 1 | | 1 |
| | 13 | **division of operations into smaller units** | 3 | 1 | 1 | | 1 |
| | 14 | **ressourceoptimyzed** | 3 | 1 | 1 | 1 | |
| | 15 | **cultural and geographics dependency** | 3 | 1 | 1 | 1 | |
| | 16 | **abstraction** | 3 | 1 | 1 | 1 | |
| | 17 | put-principle | 3 | | 1 | 1 | 1 |
| C | 18 | distinction between operations and processes | 2 | 1 | | | 1 |
| | 19 | improvements in small steps | 2 | 1 | | 1 | |
| | 20 | early error-recognition | 2 | 1 | | 1 | |
| | 21 | high education of involved people | 2 | 1 | 1 | | |
| | 22 | little hierarchy | 2 | 1 | 1 | | |
| | 23 | limited ressources | 2 | | 1 | 1 | |
| | 24 | long lifecycles | 2 | | 1 | 1 | |
| | 25 | selfregulation | 2 | | | 1 | 1 |
| D | 26 | established quality management system | 1 | 1 | | | |
| | 27 | update with intensive physical changes | 1 | | 1 | | |
| | 28 | update with little physical changes | 1 | | | | 1 |
| | 29 | short lifecycles | 1 | | | | 1 |

RM = resource management

*Fig. 3: results of attributes and their appearing in the four topics. Leading topic is the Kaizen-based Quality Management.*

The argumentation follows based on figure 3: the use of Kaizen-based tools and methods within a building design process is possible. In a next step the design process as illustrated in figure 1 is augmented. In result precision and synchronisation of different demands are added. The goal is a clear definition of the specification documents such as drawings, models, lists, etc. without loosing creativity. Creativity is moved towards the definitions of the goals and the proposed solutions, which are the areas (1) and (2) as illustrated in figure 2. Its integration in an architectural problem is shown in figures 4 and 5. The example shows as well the mutation of a possible solution into a new demand. This highly represents the iterative design process of a building.

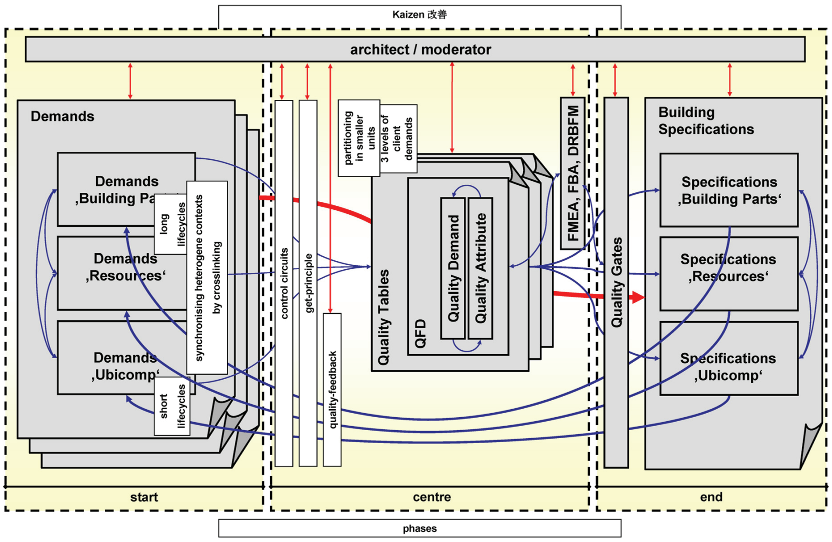


*Fig. 4: The integration of Kaizen-based tools and methods in the generalized design process as introduced in fig. 1.*

## 5. Result

As shown in the description of the process, the integration of Kaizen-based tools into the design process doesn’t kill creativity; it simply allows a more precise focus onto the core questions which need to be solved. The same time, the approach doesn’t aim for an instant and complete control of the rather complex task of defining building specifications. It aims for synchronised processing of questions which needs to be answered at the same point in the process. The application of the system described in figure 4 is visualized in figure 5. It is important to mention, that Figure 4 illustrates the integration of QM tools. It is not aimed to proposed the one and only design process. Each designer has to arrange the tools individually to the requirements of each project.

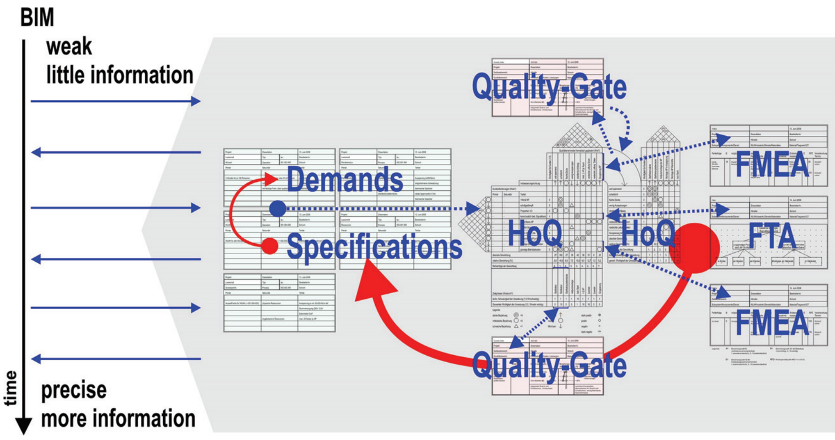


*Fig. 5: The interconnection of tools during an iterative design-task as it is developing through the time.*

Ubicomp-Kaizen takes into consideration, that Ubicomp has mainly no direct impact on a building-design, such as finishing, pre-stressed concrete-slabs or electrical light. Ubicomp-Kaizen makes use of the Kaizen-Tools like synchronisation, breaking down of processes and operations in smaller units, QFD, 'Failure Mode and Effects Analysis (FMEA)' and more recent elements such as 'Quality Gates' (Pfeifer, 2001).

In order to integrate this methodology into the contemporary and near future design process, a software tool based on the interdisciplinary thinking of BIM such as described by Bjoerk is aimed for. But the current (year 2008) definitions of the IFC lacks the representations of diverse user interactions with the building as well as the heterogeneous demands of ubicomp-based services. It is assumed that Ubicomp-Kaizen can help to define changes within the IFC. These are currently proposed as such:

- additional domain:
    - 'ubicomp services domain'
- additional elements:
    - in 'shared building services', in 'shared component elements', in 'shared building elements', in 'shared management elements', in 'shared facilities elements'
- additions to the extensions:
    - 'control', 'process'
- additions to the resource layer:
    - a new field 'quality resource', additions to 'material property resource', additions to 'constraint resource'

The tool doesn't aim for design automation nor the replacement of architect by a piece of software. It aims for computer aided design within a steadily growing field of 'conditions' to be fulfilled, such as energy codes, standards, etc. Although the methods and tools which are based on Kaizen were mainly developed in the context of serial production, their application in prototypical product development processes are well researched and proved.

## 6. Outlook

As the impact of design decisions done in early design stages are strong towards the future's sustainability and cost-performance, an application of Ubicomp-Kaizen is intended throughout a complete design process. In the early phases, this aim collides with relatively little knowledge on the buildings specifications. Adjustable techniques might support these dynamic changes. Examples in object and building scale (Scheurer et al, 2005) as well as in urban scale (Fritz, 2007) show the potential of self organizing algorithms and agent based systems to handle changing demands of multiple stakeholders. Therefore the outlook is to develop software which acts as a forerunner for BIM-models. Through the combination of these tools, a database driven software will be developed which is closely liked to a state-of-the-art BIM-software.

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